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AN INNOVATION IN CONTROL PANELS FOR LARGE COMPUTER CONTROL SYSTEMS*

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Summary

A control panel of novel design has been developed at SLAC. This panel, called a touch panel,[1] consists of a glass plate placed in front of a computer driven cathode ray tube display. Ultrasonic surface (Rayleigh) wave (8.5 MHz) beams are transmitted in a crossing X-Y grid through the glass. The intersection points of the beams form the "buttons" on the panel. The computer furnishes legends for these buttons. The presence of an operator's finger on the glass "pushing" a button is detected by the absorption of an X and a Y beam. A prototype panel has been built and used successfully with an SDS-925 computer for magnet control in the SLAC beam switchyard. A second generation panel with low parallax using the glass face of the CRT itself as the medium for ultrasonic propagation has been designed and is being constructed. An extensive software system, utilizing numerous "software panels", for general control of the accelerator, the beam switchyard, and their associated subsystems is being developed. The physical principles of the device, its advantages and disadvantages over conventional devices, current hardware and software implementation, and future plans are discussed.

Introduction

In the course of developing the SLAC beam switchyard (SDS-925) computer control system,[2] it became evident that control panels were the appropriate means for the operator to communicate with the computer. However, as more and more functions were planned for inclusion in this system, it became clear that a new panel concept was needed. A device was required which would be at the same time compact, flexible, and (relatively) inexpensive. The touch panel was conceived and developed to answer these requirements. The computer memory can store a virtually unlimited number of "software panels" of button legends and associated information which can be displayed on one or more computer driven CRT's. With a single hardware panel, an operator can control anything which is subject to computer control. Furthermore, the computer can furnish appropriate feedback to the operator in the form of graphics, alpha-numerical data, or closed circuit TV on the very same panel the operator is using for control. Figure 1 depicts a computer control system using a touch panel.

Principles and Description of Hardware Panel

The first prototype hardware panel consists of a glass plate placed in front of a cathode ray tube. Ultrasonic surface (Rayleigh)[3,4] wave (8.5 MHz) beams are transmitted in a crossing X-Y grid through the glass (see Fig. 2). The intersection points of the beams form the "buttons" on the panel. The computer driven CRT display furnishes legends for these buttons, which are seen, of course, by looking through the glass of the panel. The presence of an operator's finger on the plass "pushing" a button is detected by the simultaneous absorption of an X and a Y beam.

The first prototype model, which was satisfactorily tested in on-line operation about one year ago, has 18 ultrasonic beams (10 X or vertical beams and 8 Y or horizontal beams) on a glass placed over a standard 8 in × 10 in (HP 1300A) CRT display. The channel separation was about 0.9 in. A block diagram of an individual channel is given in Fig. 3.

A drawing of the ultrasonic portion of the circuit is given in Fig. 4. An oscillator puts an 8.5 MHz CW signal of about 6 V peak-to-peak into a 0.01 in thick ceramic crystal transducer (PZT-4). Since the input impedance of the crystal at resonance is on the order of 30 Ω, the power dissipation in the transmitting transducer is about 1/3 W; there is no significant heating. Separate oscillators are required for each channel since the resonant frequencies of the off-the-shelf crystals vary over about 10%. The crystals we used come in the form of one in disks, which when cut into pieces furnish enough for three channels. Proper frequency matching of transmitter and receiver crystals is assured by taking crystals for each beam from the same one in disk.

The PZT-4 generates a compressional wave (of velocity V_c) in the lucite transducer wedge. At the interface between the wedge and the glass some of this compressional wave is converted to a Rayleigh or surface wave (of velocity V_r) in the glass. The optimum wedge angle θ is given by $\sin\theta = V_c/V_r$. For the lucite-glass interface in our first prototype, this optimum was found to be 58.5^o. Some care should be exercised in the determination of this angle (the velocities vary somewhat depending upon the composition of the actual material). However, an error of one or two degrees causes no serious degradation in signal levels.

The surface wave energy propagates near the surface of the glass, its amplitude decaying exponentially with depth with a constant on the order of the wavelength (λ=0.015 in). The Fresnel field region of the transducer, which has a width w of 5/8 in, extends to about 25 in (w^2/λ). Thus the entire propagation path is in the Fresnel region (maximum propagation distance is about 12 in) and the beams are essentially uniform, well collimated plane waves about 1/2 in wide. However, it is evident that the transducer will project some energy outside this "beam" and the problem of adjacent channel pickup or "cross talk" must be considered. A rough worst case estimate of the problem assuming that the cross talk enters the first side lobe of the Fraunhofer[5] sin X/X distribution gives a cross talk amplitude of about 5% of the direct channel signal. The cross talk amplitude has been measured to be at the level of this estimate.

At the receiving transducer the Rayleigh wave beam is detected and a signal between 20 and 100 mV peak-to-peak in the crystal is obtained. This large variation in signal is due to the different X and Y propagation distances (a diffraction phenomenon) and to variations in the individual crystal characteristics. This signal is amplified and put into a Schmidt trigger. The Schmidt trigger threshold is set[6] at approximately 60% of the unabsorbed signal amplitude. A hysteresis of about 15% is incorporated in the trigger circuit to avoid chatter and pickup problems. When an operator's finger is placed on the glass in the ultrasonic beam path, the beam is absorbed and the Schmidt trigger so informs the computer.

The first prototype (Fig. 5) had 80 buttons (8× 10). A thin (1/32 in) plastic cover with holes 9/16 inches in diameter to guide the operator's finger to the beam intersection points was placed over the glass. This cover does not interfere with the ultrasonic surface wave propagation, or impair the quality of the CRT display, but it is a useful guide for the operator on an otherwise featureless surface. This guiding sense of touch is particularly important if the operator has to look away from the panel (e.g., to watch the current on a meter) while using it for control.

Software System

Figure 6 gives a general block diagram of the flow of touch panel information and control signals. In considering

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the software details of how the buttons generate the control signals using touch panels, one must first note that there are many different classes of buttons. For example, action may be desired at the instant when the button is first pushed, or continuously while the button is depressed, or only at the instant of release, or some combinations of these. Furthermore, buttons may be simple pushbuttons, alternate action, latching, or baled in various ways with other buttons. All of these possibilities need to be implemented in the software system.

Figure 7 shows the logic by which the touch panel button information is processed. The X and Y coordinates relate to the ultrasonic beam matrix (Fig. 2). The button program is organized to act only where a button changes state. Therefore the prior button state of the panel must be remembered. Functions requiring continuous action, such as raising a magnet current, are done by initiating and terminating a program which performs the desired process.

A panel of this configuration can understand only one button at a time. If one should push two buttons, two X and two Y beams are absorbed and there is an ambiguity in button coordinates, i.e., which X beam intersects which Y beam. The logic eliminates this problem by requiring one and only one X and Y for action (only one button at a time). If there is one and only one X and Y, a check is made that the coordinates are valid for the display. If so, the new X-Y coordinates are saved, and the appropriate action is initiated. If a second button is pushed, the logic ignores it. When the button is released its coordinates are erased and the action (if any) to be taken upon release is initiated. Whenever a button is either pushed or released, the computer actuates a relay located at the panel producing an audible click. We also plan to use visible feedback to the operator, for example, lighting the background field of the button legend when that button is pressed.

The major portion of the data associated with the panels is stored on the disk of the SDS-925 computer. This data are of several types including display data (coordinates, text, graphics, etc.), button data (valid X-Y coordinates, push commands, release commands, etc.), and status and analog data (for display). To display a panel (of button legends, say), the appropriate data is taken from SDS-925 disk and transmitted to a Data Disk 6500 Series Graphic Display System, where it is again stored on a disk in the form of a 512×512 dot matrix image. This image is then displayed as a TV raster at a 60 MHz rate in synchronism with disk rotation speed. Our basic character size is a 5×7 dot matrix; characters can be written in double width and/or height. Graphic displays can be made by using vector writing instructions (vectors are actually comprised of a line of dots). In addition, each individual dot element is separately addressable, giving full flexibility. In its present configuration our Data Disk unit can drive eight independent (black and white) displays. With the purchase of additional channels, the system can be expanded to 16 displays. Color could also be employed, but with a reduction in the maximum number of displays. Color would be desirable to convey certain types of information rapidly as is done with certain of our conventional panels.

Many functions are performed by the touch panel software. There is a button processing program which looks for touch panel input, determines the type of button, gives commands to the operating system, changes the displays, etc. Other programs update the various type of information being displayed. There is also a program to select new panels for display. This program clears the old display, outputs the new one, and does any necessary housekeeping.

Conclusion and Future Plans

The device described above has been shown to be more powerful, flexible, and compact than conventional control panels.[7] Control panels of this type can be modified or upgraded without expensive hardware modifications. They are also amenable to remote or mobile operation. And considering that one physical unit can serve a virtually unlimited number of functions, it is also cheaper than conventional techniques if one has a large system. The cost of the touch panel unit of more recent design (the second prototype) described briefly below is on the order of $1,000 for components plus some assembly time.

At the present time a second and improved prototype is under construction. It will use the glass of the CRT itself as the medium for the propagation of the ultrasonic waves, thus affording the minimum of parallax between buttons and legends. Calculations have been made showing that curved glass gives no problems beyond those of the flat glass prototype already built and operated.[10] Feasibility tests which have been made on the (safety) glass face of a 17 in CRT substantiate these conclusions. Figure 8 is a photograph of the test setup for this second prototype. Some improvements have been made in the wedge design (see Fig. 9) to increase the signal level across the glass. Namely, the transducer wedge is supported by a cantilever attached to a support post so that grease (instead of glue) can be used as a couplant between wedge and glass. This change increased the received signal amplitude by a factor of about four. Another improvement in the transducer design is the use of paraffin to adhere the ceramic crystal to the lucite wedge. This change doubles the received signal amplitude over the prior method, clamping with a grease couplant, and is simpler and cheaper.

This second prototype is being developed for use in the SLAC control room consolidation described elsewhere.[8,9]

Acknowledgements

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References and Footnotes

1. Patent applied for.

2. S. K. Howry, R. Scholl, E. J. Seppi, M. Hu, D. Neet, "The SLAC beam switchyard control computer," IEEE Trans. on Nuclear Science, NS-14, 3, 1066 (June 1967).

3. Lord Rayleigh, London Math. Soc. Proc. 17, 4 (1885).

4. There is now an extensive literature on Rayleigh waves. Cf. I. A. Viktorov, Rayleigh and Lamb Wave (Plenum Press, New York, 1967).

5. It is noted that in the Fraunhofer region (beyond w^2/λ), the characteristic beam width (the location of the first null) is λ/w or about 1.5^o. The first side lobe peaks at 2.25^o while the nearest portion of an adjacent transducer is 2.6^o off the main beam axis.

6. Actually done by varying the amplifier gain.

7. While a light pen with a CRT offers advantages similar to those of the touch panel, this approach was discarded because it was felt that requiring the operator to pick up, hold, and position something is a severe disadvantage, especially in moments of stress or crisis, precisely when one wishes to minimize problems.

8. S. K. Howry, R. Johnson, J. Piccioni, V. Waithman, "SLAC control room consolidation — software aspects," Bull. of the APS, (February 1971) p. 239 (Paper F-21 of this conference).

9. J. Berk, K. Breymayer, T. Constant, K. Crook, J. Hall, T. Huang, D. Reagan, P. Sandland, W. Struven, "SLAC control room consolidation using linked computers," Bull. of the APS, (February 1971) p. 240 (Paper F-24 of this conference).

10. While there are no additional "in principle" problems with a curved surface, the mechanical design becomes somewhat more complicated.

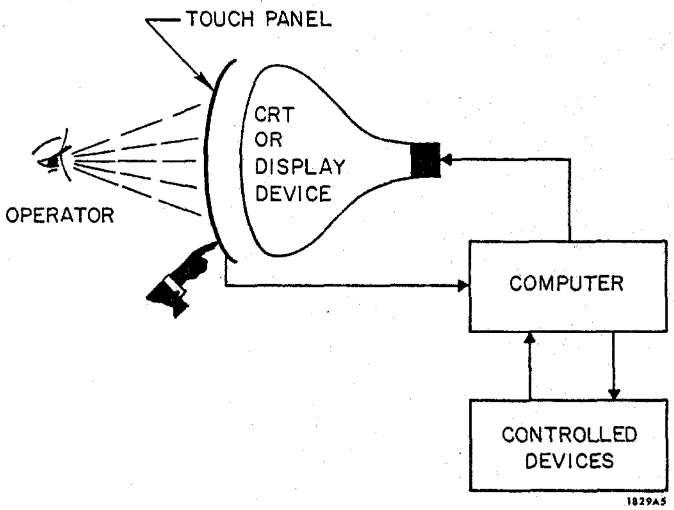

FIG. 1--General system configuration.

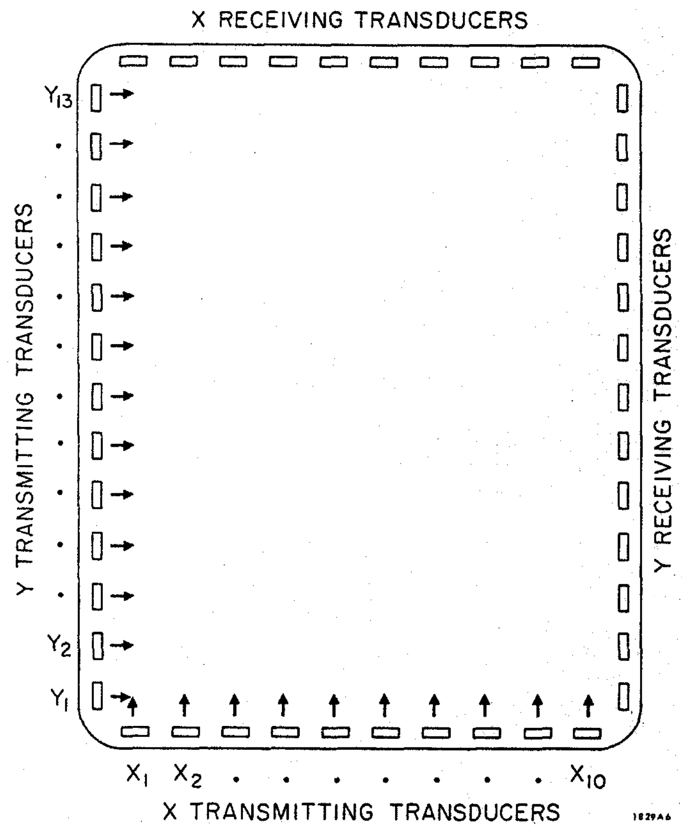

FIG. 2--10 × 13 crossing matrix of ultrasonic beams. Arrows indicate direction of propagations of Rayleigh wave beams.

FIG. 3--Block diagram of channel for ultrasonic touch panel.

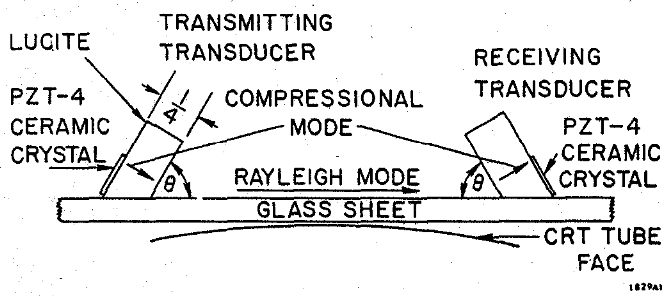

FIG. 4--Details of ultrasonic propagation.

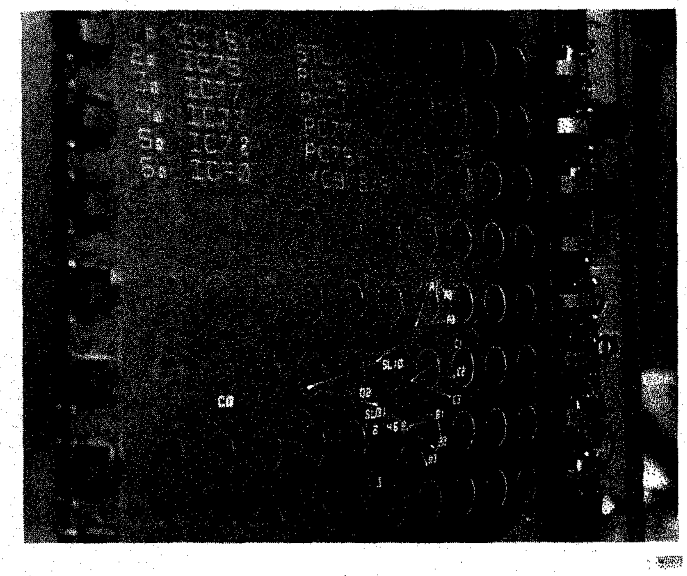

FIG. 5--Photograph of first prototype model.

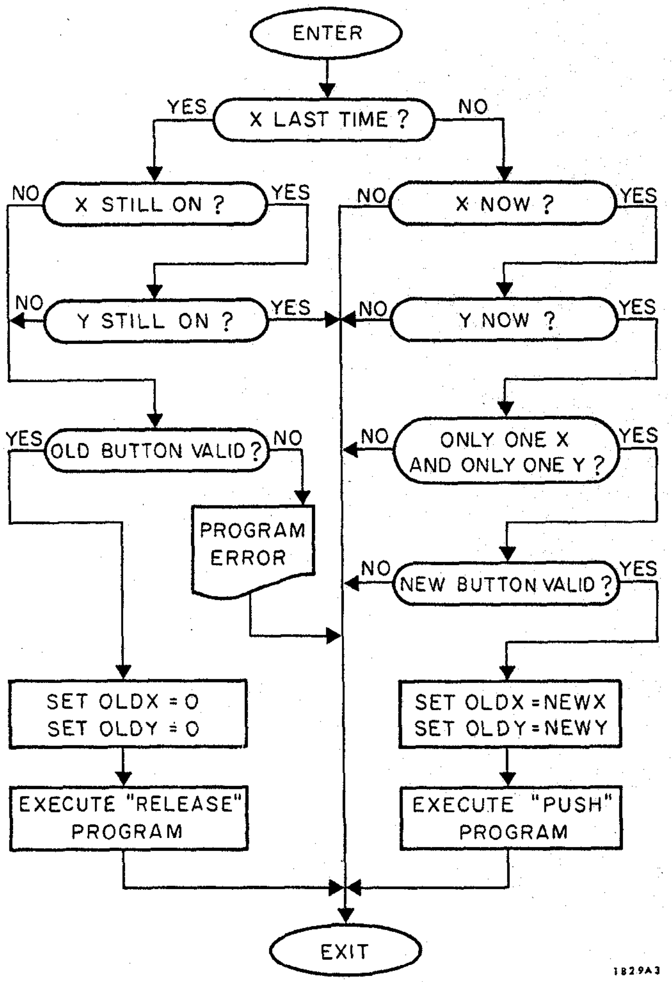

FIG. 6--Flow of control and information.

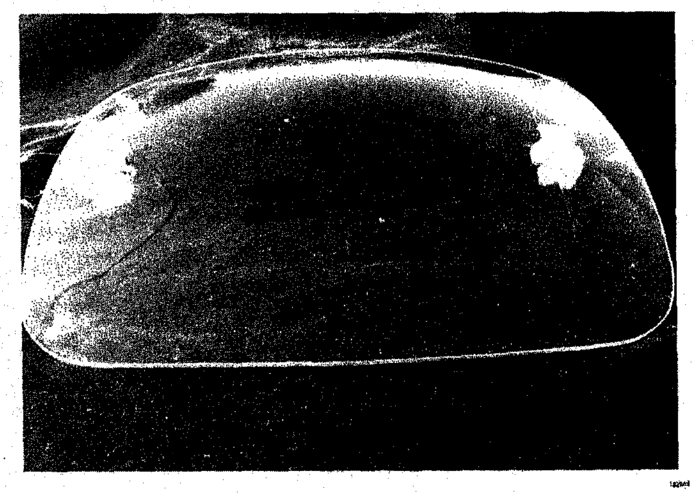

FIG. 8--Photograph of first setup for the second prototype.

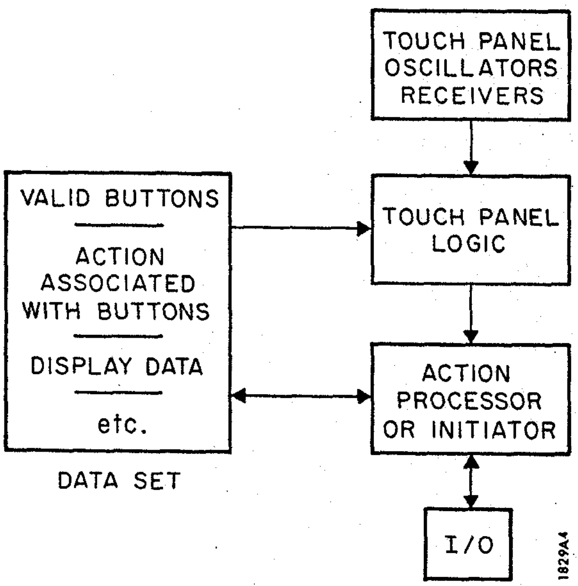

FIG. 7--Touch panel logic.

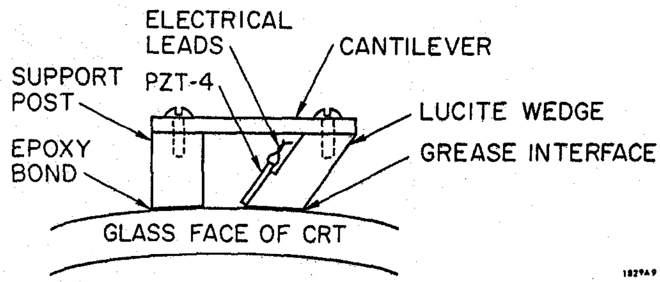

FIG. 9--New transducer design.